Citation for published version

Matsangidou, Maria and Ang, Chee Siang and Mauger, Alexis R. and Intarasirisawat, Jittrapol and Otkhmezuri, Boris and Avraamides, Marios (2018) Is Your Virtual Self as Sensational as Your Real? Virtual Reality: The Effect of Body Consciousness on the Experience of Exercise Sensations. Psychology of Sport & Exercise . ISSN 1469-0292. (In press)

DOI

Link to record in KAR

http://kar.kent.ac.uk/67624/

Document Version

Author's Accepted Manuscript

Is Your Virtual Self as Sensational as Your Real?

Virtual Reality: The Effect of Body Consciousness on the Experience of Exercise Sensations

Maria Matsangidou[1*, a], Chee Siang Ang [a], Alexis R. Mauger [b], Jittrapol Intarasirisawat [a],
Boris Otkhmezuri [a], Marios N. Avraamides [c]

[a] Department of Engineering and Digital Arts, University of Kent, Kent, UK

[b] School of Sport and Exercise Sciences, University of Kent, Kent, UK

[c] Department of Psychology, University of Cyprus, Nicosia, CY

RISE: Research centre on Interactive media, Smart systems and Emerging technologies, Nicosia, CY

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[1] *Correspondence: M.Matsangidou@kent.ac.uk

ABSTRACT

Objectives: Past research has shown that Virtual Reality (VR) is an effective method for reducing the perception of pain and effort associated with exercise. As pain and effort are subjective feelings, they are influenced by a variety of psychological factors, including one's awareness of internal body sensations, known as Private Body Consciousness (PBC). The goal of the present study was to investigate whether the effectiveness of VR in reducing the feeling of exercise pain and effort is moderated by PBC.

Design and Methods: Eighty participants were recruited to this study and were randomly assigned to a VR or a non-VR control group. All participants were required to maintain a 20% 1RM isometric bicep curl, whilst reporting ratings of pain intensity and perception of effort. Participants in the VR group completed the isometric bicep curl task whilst wearing a VR device which simulated an exercising environment. Participants in the non-VR group completed a conventional isometric bicep curl exercise without VR. Participants' heart rate was continuously monitored along with time to exhaustion. A questionnaire was used to assess PBC.

Results: Participants in the VR group reported significantly lower pain and effort and exhibited longer time to exhaustion compared to the non-VR group. Notably, PBC had no effect on these measures and did not interact with the VR manipulation.

Conclusions: Results verified that VR during exercise could reduce negative sensations associated with exercise regardless of the levels of PBC.

Keywords: Virtual Reality, Pain Intensity, Perceived Exhaustion, Heart Rate, Physical Activity, Private Body Consciousness

Introduction

Experiencing pain causes discomfort to the individual as a result of actual or believed tissue injury (Merskey & Bogduk, 1994). As such, pain is both nociceptive and subjective, with the same sensory signal giving rise to different experiences of pain intensity across individuals and situations. Research has shown that psychological factors, such as expectations based on visual information, play a vital role in pain experience (Bayer, Coverdale, Chiang, & Bangs, 1998; Ohrbach, Crow, & Kamer, 1998; Zatzick & Dimsdale, 1990). Moreover, although not all pain represents a danger to the body, the experience of pain may lead to undesirable behavior change. For example, the naturally occurring pain caused by vigorous exercise does not pose physical harm but it may still cause people to steer clear from exercise in order to avoid the painful experience (Mauger, 2014).

Recent research has shown that beyond expectations created on the basis of visual information, the level of pain one experiences depends on other factors such as Private Body Consciousness (PBC), i.e., how well one is aware of internal bodily sensations (Bekker, Croon, van Balkom, & Vermee, 2008; Haugstad et al., 2006; Miller, Murphy, & Buss, 1981). Indeed, studies with both clinical patients and healthy participants have shown that individuals scoring higher on a PBC measure reported greater frequency and intensity of pain symptoms compared to those with lower scores of PBC (Ahles, Pecora, & Riley, 1987; Ferguson & Ahles, 1998; Martin, Ahles, & Jeffery, 1991; Mehling et al., 2009; Pincus, Burton, Vogel, & Field, 2002). These findings suggest that effectiveness of interventions aimed at reducing pain sensations may depend on an individual's PBC level. In the present study we investigate this hypothesis, for an intervention that relies on Virtual Reality (VR) technology.

VR allows users to experience a computer-simulated reality based on visual cues, enhanced with auditory, tactile and olfactory interactions (Li, Montaño, Chen, & Gold, 2011). In recent years, low-cost consumer VR gear has become widely available (e.g., Google Cardboard, Gear VR, Oculus Rift, HTC Vive[2]), providing a wide range of opportunities for applications, including interventions for reducing exercise-related pain and effort.

Indeed, research shows that VR technology may provide an alternative solution to pain management that does not rely on the use of pharmacological analgesics (Mahrer & Gold, 2009; Malloy & Milling, 2010; Matsangidou, Ang, & Sakel, 2017; Morris, Louw, & Grimmer-Somers, 2009). Although VR has been shown to be effective in reducing the feelings of pain and effort (Matsangidou, Ang, Mauger, Otkhmezuri, & Tabbaa, 2017), the mechanisms by which it does so, remain largely unknown. One possibility is that VR reduces the amount of attention that is allocated to the sensory signal of pain. Our attentional resources are limited and to cope with the vast array of information that gets registered by our senses at any given point in time, we must select only the information that is relevant to our goal and ignore the rest (e.g., Wickens, 2008.) VR provides the senses of the user with a multitude of information while at the same time prevents access to his/her body. This allows the user to be immersed in the virtual environment and disconnect from the actual surroundings (e.g., Eichenberg & Wolters, 2012). As a result, attentional resources may be diverted away from the pain signal, reducing thus the experience of pain (Gold, Belmont, & Thomas, 2007; McCaul & Malott, 1984).

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[2] https://store.google.com/product/google_carboard, www.samsung.com/global/galaxt/wearables/gear-vr , www.oculus.com, www.vive.com

If indeed VR helps to distract users away from the pain signal, then its effectiveness for reducing the feelings of pain would depend on how well the user can inhibit information about his/her body and how well s/he can immerse in the virtual environment. Given that people with higher PBC are believed to be better attuned to their internal physiology and are more affected by nociceptive stimuli (Fenigstein, Scheier, & Buss, 1975; Miller et al., 1981), it may be that VR is less effective in reducing their pain and effort perception compared to those with low PBC. This hypothesis has not yet been tested as, to our knowledge, no study so far has investigated whether PBC can moderate the positive effect of VR on exercise-related pain perception. Therefore, the goal of the current study is (1) to verify that VR can be effective in reducing the feeling of exercise-induced pain, and (2) to examine whether its effect depends on PBC. If PBC influences the levels of presence/immersion in the virtual environment and as a result the attention allocated to pain signal, participants with low PBC scores are expected to report less pain and effort compared to participants with high PBC scores. Alternatively, if PBC does not moderate the effect of VR, based on past VR studies enhanced with several psychological intervention strategies (Mahrer & Gold, 2009; Malloy & Milling, 2010; Morris et. al., 2009), we still expect the VR group to report lower pain and effort than the non-VR control group.

Material and Methods

Participants

Twenty-one males and 59 females, with a mean age of 23 years (SD = 5) participated in the study. Participants' one-repetition maximum (1RM[3]), for 180° of dominant arm elbow flexion ranged from 5 to 30 kg, with a mean at 11.9 kg (SD = 6.2). More than half of the participants reported not engaging in regular (3 to 7 days per week), structured resistance or aerobic exercise (no regular resistance training = 52/80, no regular aerobic training = 51/80 during the testing week). Participants who reported engaging in regular structured exercise (regular resistance training = 28/80, regular aerobic training = 29/80) had a weekly mean workout time of 2.81 hours (SD = 3.75). All participants were healthy, with normal or corrected vision, and no disability that could affect their performance in the exercise task. In addition, no participant reported taking any chronic medication or having any cardiovascular, mental, or brain condition that could affect their performance. Participants were randomly allocated to the VR or the non-VR group. **Error! Reference source not found.** presents relevant descriptive data for each condition.

Table 1

Descriptive statistics per group

Intervention	Sex		Age, years	1RM, kg	Participants undertaking regular Exercise		Workout time, h (M, SD)
	Males	Females	(M, SD)	(M, SD)	Resistance	Aerobic	
VR	9	31	23.58, 5.35	12.35, 6.35	16/40	14/40	2.91, 3.69

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[3] i.e. the heaviest weight they could lift.

non-VR	12	28	22.65, 6.40	11.60, 6.29	12/40	15/40	2.70, 3.85

Ethics

The study was approved by University of Kent SSES Research Ethics & Advisory Group (ref. Prop. 50_2016_17). All participants signed a consent form prior to the study and the study was performed in accordance with the Declaration of Helsinki.

Procedure

The procedure followed in the study is presented schematically in **Error! Reference source not found.**. Upon arriving at the laboratory the first day, participants were assigned to the VR or non-VR group and were asked to complete a PBC questionnaire. Then, they were asked to stand with their back straight against the wall and with their elbow and wrist joint at a 180° angle. From this position, they were asked to bicep curl a dumbbell through a full range of motion (180°-full flexion-180°). Weight was added to the dumbbell until the participant was no longer able to perform a 180°-full flexion-180°. The heaviest weight a participant was able to lift defined their 1RM. A mass that was equal to the 20% of each participant's 1RM was then set as their Baseline Mass.

Once this process was completed, participants were asked to rest for 10 minutes before moving on to the familiarization session. During the familiarization session, they were instructed to sit on a chair and rest their elbow on a table in front of them. A yoga mat was placed under their elbow to increase comfort. Participants in the VR group were asked to put on a Samsung Galaxy Gear[1] head-mounted-display (HMD). Then, participants in both groups were instructed to hold their Baseline Mass in an isometric contraction for as long as they could with their elbow at an angle of 90° flexion.

When participants visited the laboratory the second day for the main experiments(VR and non-VR sessions), they were again instructed to sit on a chair with their elbow rested on a table in front of them and perform the exercise task as they did during their first visit. Once the exercise was completed, participants in the VR group answered a questionnaire that included a series of items inquiring about their experience with the VR.

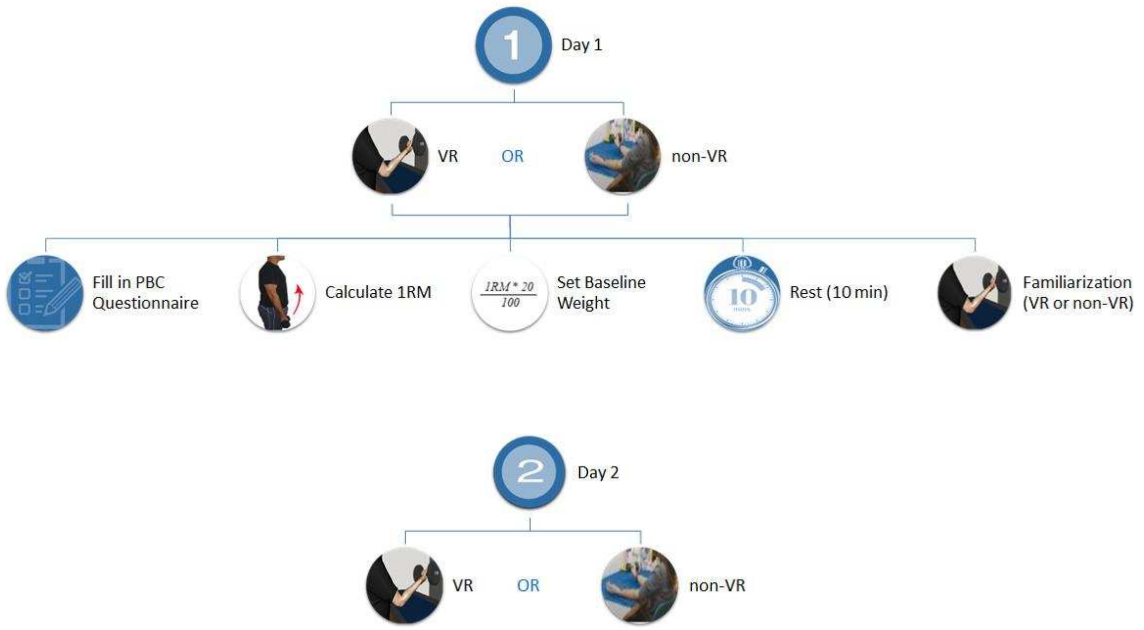

Figure 1. Illustration of the Study Procedure.

Apparatus and Visual Information

Participants in the VR group viewed from a first person perspective their virtual body sitting on a chair in a neutral looking virtual room (**Error! Reference source not found.**). A table with a yoga mat on it was present in the virtual room, simulating the look of the actual environment. The participant's virtual arm was shown to hold the dumbbell in the 90º position. Participants in the non-VR group sat on a chair in an empty room, in front of a table with a yoga mat on it, looking directly at their arm holding the weight at the 90º position.

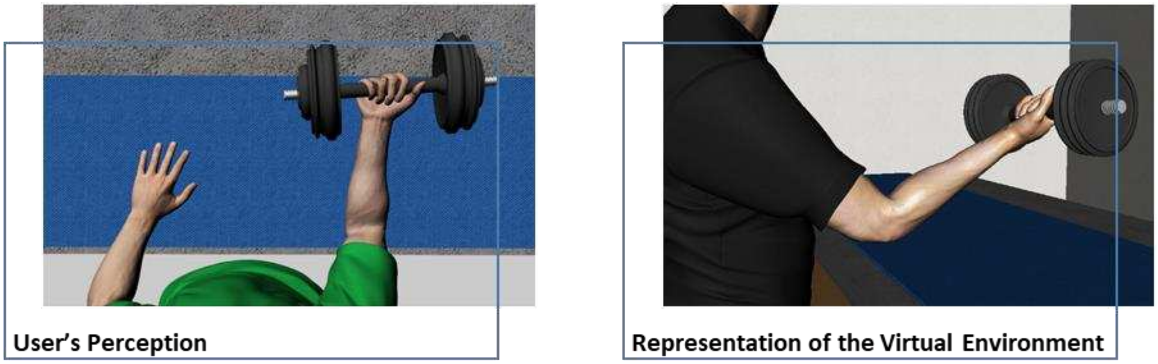

Figure 2. Illustration of User's Perception and Virtual Environment.

The VR environment was developed with the Unity3D 5 game engine for the Samsung Gear VR HMD and ran on a Samsung Galaxy S6 phone. The 3D models were generated in Maya version 2016 (Autodesk Inc). The system allowed customizing the gender, the dominant hand, the skin, the t-shirt colors, and the weights on the dumbbell. In order to provide a sense of agency, the VR was connected to a Microsoft Band (Microsoft Inc.) that tracked the movement of the participant's arm (rotation X and Y axis) using its built-in gyroscope. The data were used to animate the virtual arm in real time to match the movement of the actual arm.

Instruments

During the two sessions of the study (i.e., the familiarization and intervention sessions), the following data were collected:

Heart Rate (HR): HR was measured continuously with a telemetric device (Polar Electro, N2965, Finland). HR provides a measure of the psychological anticipation of exercise and has been used in several previous studies relating to pain (e.g., McGrath et al., 2008; Matsangidou et al., 2017; von Baeyer & Spagrud, 2007).

Time to Exhaustion (TTE): TTE was defined as the amount of time participants spent holding the weight. Time to Exhaustion of pain has been previously assessed during a continuous pain task (Astokorki & Mauger, 2017; Dahlquist, Herbert, Weiss, & Jimeno, 2010; Rutter, Dahlquist, & Weiss, 2009; Sil et al., 2014). For health and safety reasons, the maximum experimental time was set to 15.00 minutes.

Pain Intensity Rating (PIR): Participants were asked to verbally report their level of perceived pain every 60s, using the 0-10 Cook Scale that ranged from 0 (No pain at all) to 10 (Extremely intense pain, almost unbearable). Participants were instructed to report their pain intensity according to feelings of pain during exercise, rather than compared to other non-exercise type pain (e.g. dental pain). The PIR scale has been previously shown to have high reliability and validity (Cook, O'Connor, Eubanks, Smith, & Lee, 1997). Our analysis supports previous findings and revealed a high degree of reliability, measured by Cronbach alpha, $\alpha = .920$.

Rating of Perceived Exertion (RPE): Participants were asked to verbally provide a rating of perceived exertion, using the 6-20 Borg Scale that ranged from 6 (No exertion at all) to 20 (Maximal exertion), every 60s of the exercise task. Specifically, participants were asked to report how much effort they had to exert to keep their arm in a 90º flexion, independent of feelings of discomfort. The RPE scale has also been shown to have high reliability and validity (Borg, 1998). Our results support previous findings, revealing high reliability, $\alpha = .886$.

Private Body Consciousness (PBC): PBC scores (Miller et al., 1981) were obtained through a self-report scale consisting of 5 statements directed at capturing the level of awareness of one's internal body sensations (i.e. "I am sensitive to internal body tensions", "I know immediately when my mouth or throat gets dry", "I can often feel my heart beating", "I am quick to sense the hunger contractions of my stomach", "I'm very aware of changes in my body temperature"). Statements were rated using a 5-point Likert scale, ranging from 0 (Extremely uncharacteristic) to 4 (Extremely characteristic). Higher scores represent greater body awareness (Ainley & Tsakiris, 2013). The PBC questionnaire has high reliability and validity (Miller et al., 1981; Mehling et al., 2009). Previous findings were supported by our analysis showing high of reliability, α = .663.

Immersive Experience: A self-report questionnaire completed after the exercise task in the VR group was used to assess immersive experience. The questionnaire consists of several factors such as Presence and Hand Ownership, based on the individual's impression of realistic experience, rated on a 7-point Likert scale. The Immersive Experience questionnaire has been shown to have high reliability and validity (Matsangidou et al., 2017). Our analysis supports previous findings and revealed a high reliability for the components of presence and hand ownership, α = .838 and α = .955 respectively.

Statistical Analysis

Data analyses on time-based measures (PIR, RPE, HR) were carried out using the ISO time-points that were consistent across all participants. The shortest time to task failure across participants and groups was 2 minutes; therefore, the ISO time analysis was carried out for the first and the second minutes of the exercise task (hereafter referred to as PIR1, RPE1, HR1 and PIR2, RPE2, HR2). HR was also recorded when participants withdrew from the task (fHR). The average PIR, RPE, and HR (mPIR, mRPE, mHR) were computed across the exercise task for each participant. A correlation analysis (Pearson's r) was conducted to explore potential relations among PBC, Immersive Experience (Presence and Hand Ownership), PRI, RPE, and HR. An Analysis of Covariance (ANCOVA) was also conducted to examine how VR (as an independent variable) and PBC (as a covariate) affect TTE, PIR, RPE, and HR. Means (M) and standard deviations (SD) are reported. For statistical tests a=.05 was used to test significance.

Results

To evaluate the main hypothesis of the study, i.e., that the influence of VR on time to exhaustion (TTE), pain (PIR1 and PIR2, and mPIR) and effort (RPE1, RPE2, mRPE) perception depends on PBC, we conducted a series of one-way ANCOVAs. Additional one-way ANCOVAs were also conducted on ISO HR (HR1 and HR2), mean (mHR) and on end of exercise (fHR) variables, with VR condition as the independent variable and the PBC as a covariate. We present these analyses for each measure of interest.

Pain Intensity Rating (PIR).

The analysis revealed a significant effect of VR condition for PIR1, PIR2 and mPIR. For the PIR1, the effect of the VR exercise, after controlling for PBC, was significant, with participants reporting lower PIR in the VR (M = 2.28, SD = 1.68) than the non-VR (M = 3.20, SD = 1.70) exercise condition, (F(2, 76) = 5.83, p = 0.018, $\eta^2 = 0.07$) (**Error! Reference source not found.**). However, the effect of PBC was not significant (F(2, 76) = 0.39, p = 0.54, $\eta^2 = 0.005$). The same pattern of findings was obtained for PIR2. The effect of VR was again significant (F(2, 76) = 6.09, p = 0.016, $\eta^2 = 0.073$) (M = 6.56, SD

= 1.33) (**Error! Reference source not found.**), with reported PIR being lower for the VR (M = 4.61, SD = 2.42) than the non-VR (M = 5.87, SD = 2.16) exercise condition. The effect of PBC was not significant (F(2, 76) = 0.92, p = 0.342, $\eta^2 = 0.012$).

The effect of the VR condition on mPIR after controlling PBC was also significant, (F(2, 76) = 5.09, p = 0.027, $\eta^2 = 0.062$). Reported mPIR was lower in the VR (M = 5.84, SD = 1.55) than the non-VR exercise (M = 6.56, SD = 1.33). However, the effect of PBC was not significant (F(2, 76) = 2.49, p = 0.119, $\eta^2 = 0.031$).

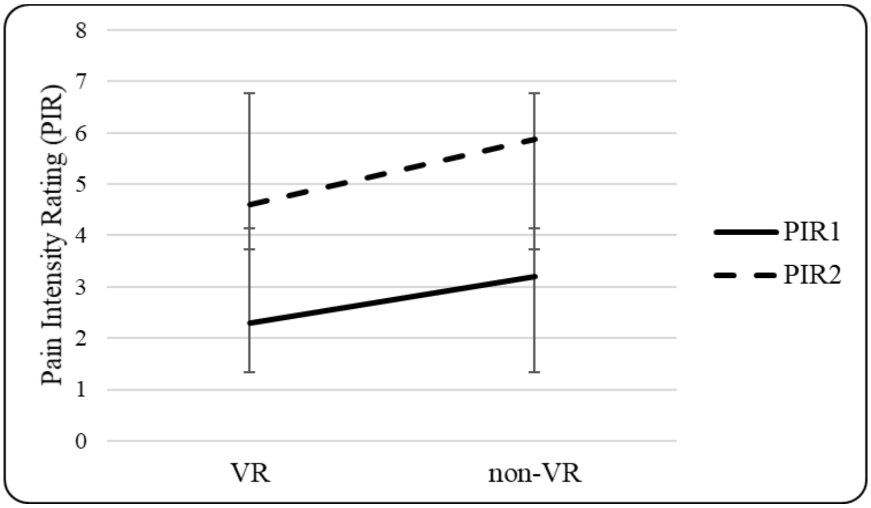

Figure 3. VR effect on PIR1 and PIR2 (error bars represent standard errors of the mean).

Rating of Perceive Exertion (RPE).

For perceived exertion of the analyses for each time point (RPE1 and RPE2) revealed that for RPE1 neither the main effect of VR condition nor the main effect of PBC were significant (F(2, 76) = 1.71, p = 0.194, $\eta^2 = 0.022$ and F(2, 76) = 0.96, p = 0.329, $\eta^2 = 0.012$ respectively). For RPE2, the effect of VR condition was significant, (F(2, 76) = 4.52, p = 0.037, $\eta^2 = 0.055$), with participants in the VR exercise (M = 11.53, SD = 3.10) reporting lower RPE rates than those in the non-VR exercise condition (M = 13.03, SD =

3.32). The main effect of PBC was not significant for RPE2 ($F(2, 76) = 2.29$, $p = 0.134$, $\eta^2 = 0.029$).

The analysis on the mean rates of perceived exertion (mRPE), showed a statistically significant difference between the VR and non-VR exercise on mRPE after controlling for PBC, ($F(2, 76) = 4.64$, $p = 0.034$, $\eta^2 = 0.057$). Participants reported overall lower RPE in the VR (M = 13.32, SD = 2.51) than in the non-VR exercise condition (M = 14.42, SD = 2.17). The main effect of PBC was not significant ($F(2, 76) = 3.09$, $p = 0.082$, $\eta^2 = 0.039$).

Time to Exhaustion (TTE).

The ANCOVA on the Time to Exhaustion (TTE) revealed a statistically significant effect of VR condition. , ($F(2, 76) = 12.59$, $p = 0.001$, $\eta^2 = 0.141$), with participants lasting longer in the VR (M = 05.34 min, SD = 1.55) than in the non-VR exercise (M = 04.14 min, SD = 1.22). As with the RPE analyses, the main effect of PBC was not significant ($F(2, 76) = 0.87$, $p = 0.355$, $\eta^2 = 0.011$).

Heart Rate (HR).

The analyses showed no significant effect of the VR condition on the dependent Heart Rate (HR1, HR2, mHR, and fHR) variables after controlling the PBC. The results from these analyses are presented in **Error! Reference source not found.**. As seen in Table 2, there was a trend for participants who had exercised in VR to have a lower HR (~3 bpm lower) than participants who had exercised outside VR.

Table 2

HR: Effects for VR and non-VR exercise after controlling the PBC

Dependent	df	df error	F	Intervention	Mean (bpm)	SD	95% Confidence Interval	
							Lower Bound	Upper Bound
HR1	2	76	0.95	VR	85.78	11.77	81.89	89.63
				non-VR	88.43	12.75	84.57	92.31
HR2	2	76	1.53	VR	86.95	11.96	83.32	90.55
				non-VR	90.10	10.93	86.50	93.73
mHR	2	76	0.19	VR	87.35	11.50	83.79	90.87
				non-VR	90.63	10.95	87.11	94.19
fHR	2	76	1.78	VR	89.75	11.58	86.17	93.30
				non-VR	93.10	11.13	89.55	96.68

PBC and its correlates.

To test the hypothesis that PBC levels are related to the levels of presence and immersion reported by participants, we carried out a correlation analysis. Results showed no significant correlation between participant ratings of immersive experience and the PBC within the VR group (r(40) = -0.16, p = 0.31) for presence and PBC, and (r(40) = -0.20, p = 0.21) for hand ownership and PBC.

We carried an additional analysis to examine whether PBC levels are related to pain perception (PRI), effort (RPE), and HR.As shown in Table 3, no significant correlations were found among these measures

Table 3

PBC, HR, PIR and RPE ratings: Correlations (N = 80), (*p < .05; **p < .01)

	1	2	3	4	5	6	7	9	10
1. PBC	-								
2. HR1	0.10	-							
3. HR2	0.10	$.91^{**}$	-						
4. fHR	0.13	$.83^{**}$	$.90^{**}$	-					
5. mHR	0.10	$.95^{**}$	$.97^{**}$	$.95^{**}$	-				
6. PIR1	0.07	0.00	0.10	0.12	0.07	-			
7. PIR2	0.10	0.08	0.16	0.18	0.14	$.86^{**}$	-		
9. RPE1	0.11	-0.12	-0.01	0.03	-0.03	$.66^{**}$	$.55^{**}$	-	
10. RPE2	0.16	-0.05	0.07	0.12	0.04	$.68^{**}$	$.71^{**}$	$.82^{**}$	-

Discussion

The aim of the present study was to examine whether VR technology reduces the perception of pain and effort during exercise and whether PBC moderates this effect. Findings revealed that VR was effective in reducing exercise-induced pain for this sample of 18 to 45-year old adults of both genders. Indeed, results showed a substantial decrease in participant PIR and RPE during exercise in VR compared to the control condition of exercise without VR. Notably, this was apparent from the first minute of exercise. The mean PIR in the first minute of the VR session was 10% lower than the corresponding time point in the non-VR exercise, although this difference increased to 13% in the following minute. During the second minute of exercise, participants' RPE was by 11% lower in the VR than in the non-VR exercise. This observation is consistent with previous research demonstrating that VR enhanced by psychological methods, such as Distraction via imagery, meditation, relaxation, hypnosis, and positive thinking is capable of reducing the naturally occurring pain and effort associated with single limb exercise (Matsangidou et. al., 2017).

Another important finding from the study was that the effect of VR exercise on PIR and RPE was independent of participants' levels of PBC. We had hypothesized that if VR helps to distract one away from the pain signal, then its effectiveness for reducing the feelings of pain would depend on how well information about one's body can be inhibited. Thus, we expected participants with low PBR to show increased sensitivity to VR exercise. However, this was not the case. Instead, our results provide clear evidence that PBR does not interact with VR in reducing perceived pain.

Although no effect of PBR was observed, the obtained lower PIR and RPE during the VR session could still be still be attributed to inattention. VR provides the individual with a variety of simultaneous sensory signals which may direct the individual's attention away from the painful signal (Gold et al., 2007; McCaul & Malott, 1984; Wickens, 2008). Past research has shown that a significant component of the effectiveness of VR for pain management is the high level of immersion and presence it delivers. Immersion induces a state of consciousness in which the user's responsiveness to its own physical self-diminishes due to the user's involvement in the Virtual Environment (VE). As the user engages strongly with this sensory experience, s/he may become less attentive to nociceptive signals and pain.

Another possible explanation for why VR in our study was effective in reducing pain and perceived exertion is that participants embodied the simulation and felt the virtual hand as their actual hand. If this was the case, the simulation of the hand via VR concealed visual stimuli that could be perceived as signals of pain and exertion (e.g., veins swells, skin redness). Previous research has indeed shown that bodily self-consciousness is generated in the brain by sensory stimulation on a fake hand, which can be perceived by the individual as a real part of the body (Botvinick & Cohen, 1998; Tsakiris, Hesse, Boy, Haggard, & Fink, 2006). As in our study the movement of the virtual hand was realistically mapped to that of the real hand, participants were very likely to have felt the virtual hand as their own. This possibility is corroborated by the high scores of hand ownership reported by our participants.

Finally, the effect of VR could be attributed to relaxing attributed of the simulated environment. Previous research has shown that viewing an animated cartoon helps to reduce anxiety in clinical environments (Cohen, Blount & Panopoulos, 1997; Lee et al., 2012) and that a cartoonish virtual environment is associated with happy childhood memories and improved mood (Bower, 1981; Martin & Metha, 1997). Given that in the present study a cartoonish environment was presented (as opposed to a photorealistic one), our paradigm could have induced a similar relaxing reaction as that reported in previous studies (Bower, 1981; Cohen et al., 1997; Lee et al., 2012; Martin & Metha, 1997), which counteracted the negative sensations associated with exercise.

Another notable finding from the current study is the positive relationship between VR and time to exhaustion (TTE). As results showed, participants using VR exercised for approximately two minutes longer compared to those who carried out the conventional non-VR exercise. This finding is in line with results from previous research showing that VR technology can be used as an effective means for altering time perception via Distraction and Altered Visual Feedback strategies, during chemotherapy, during therapy for individuals experiencing induced ischemic pain, and during exercise induced pain (Matsangidou et al., 2017; Schneider & Hood, 2007; Schneider, Kisby, & Flint, 2011; Schneider & Workman, 2000; Schneider et al., 2003; Schneider, Prince-Paul, Allen, Silverman, & Talaba, 2004; Wiederhold & Wiederhold, 2007). Our study suggests that VR technology is not just a platform for the implementation of traditional and successful psychosocial intervention strategies. Rather, it can contribute to the alteration of time perception, the reduction of pain, and hence the increase of the perceived duration of the painful process even without any concurrent psychological intervention.

The observed trend towards a reduced HR during exercise in VR supports the existing evidence suggesting that affordable VR technology can be effective in reducing physiological and psychological strain during exercise (Matsangidou et al., 2017). Even though it was not significant, during the VR session the participants had approximately 3 bpm lower mean HR than the participants in the non-VR group. This observation was supported by both the ISO time, mean and end of exercise data. It may be that the novelty afforded by the virtual environment had an effect which served to reduce anxiety and attention to these as they increased as a result of exercise (Arntz, Dreessen, & Merckelbach, 1991).

Further results from the current study showed no significant effect of PBC on immersion, assessed through presence and hand ownership scores. This results are at odds with those from previous research showing that individuals who score higher in PBC tend to better understand their body than individuals which scores lower in PBC (Miller et al., 1981). Instead, our results showed that PBC was not a predictor for presence and hand ownership in a VR environment and that the positive effect of VR technology for pain management during exercise was not mediated by PBC.

Future research may investigate the conditions under which PBC may influence immersion and potentially the effectiveness of VR. For example, more research is needed to determine whether the virtual environments representing natural and photorealistic environments are more or less effective than ones presented in cartoonish form. Furthermore, it would be worthwhile adopting a mixed-methods approach (questionnaire and interview) in order to address user preferences for the design of VR environments. Finally, this study utilized participants who were both active and inactive, therefore future work should seek to replicate this study with a group of sedentary participants, as this is where the greatest potential for positive impact on behavior may be.

In conclusion, the results of this study provide evidence that VR technology can play a significant role in reducing the sensations of pain and effort caused by exercise. In particular, our findings showed that using VR during exercise can help to offset pain perception and perceived effort, even for individuals who score high in PBC. These findings open possibilities of investigating the use of VR technology for improving immersion and interest and reducing negative exercise-associated sensations during home based exercise training.

References

Ahles, T. A., Cassens, H. L., & Stalling, R. B. (1987). Private body consciousness, anxiety and the perception of pain. Journal of Behavior Therapy and Experimental Psychiatry, 18(3), 215-222. doi: 10.1016/0005-7916(87)90003-6.

Ahles, T. A., Pecora, L., & Riley, S. (1987). Self-focused attention, symptoms, and chronic pain: a hypothesis. Southern Psychologist, 3, 25-28.

Ainley, V., & Tsakiris, M. (2013). Body conscious? Interoceptive awareness, measured by heartbeat perception, is negatively correlated with self-objectification. PloS one, 8(2), e55568. doi: 10.1371/journal.pone.0055568.

Arntz, A., Dreessen, L., & Merckelbach, H. (1991). Attention, not anxiety, influences pain. Behaviour Research and Therapy, 29(1), 41-50. doi: 10.1016/S0005-7967(09)80006-5.

Astokorki, A.H., & Mauger, A.R. (2016). Tolerance of exercise-induced pain at a fixed rating of perceived exertion predicts time trial cycling performance. Scandinavian Journal of Medicine & Science in Sports, 27(3), 309-317. doi: 10.1111/sms.12659.

Bayer, T. L., Coverdale, J. H., Chiang, E., & Bangs, M. (1998). The role of prior pain experience and expectancy in psychologically and physically induced pain. Pain, 74(2-3), 327-331. doi: 10.1016/S0304-3959(97)00196-6.

Bekker, M. H., Croon, M. A., van Balkom, E. G., & Vermee, J. B. (2008). Predicting individual differences in autonomy-connectedness: the role of body awareness, alexithymia, and assertiveness. Journal of Clinical Psychology, 64(6), 747-765. doi: 10.1002/jclp.20486.

Borg, G. (1998). Borg's perceived exertion and pain scales. Human kinetics.

Botvinick, M., & Cohen, J. (1998). Rubber hands ‘feel’ touch that eyes see. Nature, 391, 756.

Bower, G. H. (1981). Mood and memory. American Psychologist, 36(2), 129-148. doi: 10.1037/0003-066X.36.2.129.

Cohen, L. L., Blount, R. L., & Panopoulos, G. (1997). Nurse Coaching and Cartoon Distraction: An Efective and Practical Intervention to Reduce Child, Parent, and Nurse Distress During Immunizations. Journal of Pediatric Psychology, 22(3), 355-370. doi: 10.1093/jpepsy/22.3.355.

Cook, D. B., O'Connor, P. J., Eubanks, S. A., Smith, J. C., & Lee, M. I. N. G. (1997). Naturally occurring muscle pain during exercise: assessment and experimental evidence. Medicine and Science in Sports and Exercise, 29(8), 999-1012. doi: 10.1093/jpepsy/22.3.355.

Dahlquist, L. M., Herbert, L. J., Weiss, K. E., & Jimeno, M. (2010). Virtual-reality distraction and cold-pressor pain tolerance: does avatar point of view matter? Cyberpsychology, Behavior and Social Networking, 13(5), 587–591. doi: 10.1089/cyber.2009.0263.

Eccleston, C., Crombez, G., Aldrich, S., & Stannard, C. (1997). Attention and somatic awareness in chronic pain. Pain, 72(1), 209-215. doi: 10.1016/S0304-3959(97)00030-4.

Eichenberg, C., & Wolters, C. (2012). Virtual Realities in the treatment of mental disorders: A Review of the current state of research. Virtual Reality in Psychological, Medical and Pedagogical Applications, 2, 35-64. doi: 10.5772/50094.

Fenigstein, A., Scheier, M. F., & Buss, A. H. (1975). Public and private self-consciousness: Assessment and theory. Journal of Consulting and Clinical Psychology, 43(4), 522-527. doi: 10.1037/h0076760.

Ferguson, R. J., & Ahles, T. A. (1998). Private body consciousness, anxiety and pain symptom reports of chronic pain patients. Behaviour Research and Therapy, 36(5), 527-535. doi: 10.1016/S0005-7967(98)00048-5.

Gold, J. I., Belmont, K. A., & Thomas, D. A. (2007). The neurobiology of virtual reality pain attenuation. CyberPsychology & Behavior, 10(4), 536-544. doi: 10.1089/cpb.2007.9993.

Haugstad, G. K., Haugstad, T. S., Kirste, U. M., Leganger, S., Wojniusz, S., Klemmetsen, I., & Malt, U. F. (2006). Posture, movement patterns, and body awareness in women with chronic pelvic pain. Journal of Psychosomatic Research, 61(5), 637-644. doi: 10.1016/j.jpsychores.2006.05.003.

Hoffman, H. G., Seibel, E. J., Richards, T. L., Furness, T. A., Patterson, D. R., and Sharar, S. R. (2006). Virtual reality helmet display quality influences the magnitude of virtual reality analgesia. The Journal of Pain, 7(11), 843-850. doi: 10.1016/j.jpain.2006.04.006.

Lee, J., Lee, J., Lim, H., Son, J. S., Lee, J. R., Kim, D. C., & Ko, S. (2012). Cartoon distraction alleviates anxiety in children during induction of anesthesia. Anesthesia & Analgesia, 115(5), 1168-1173. doi: 10.1213/ANE.0b013e31824fb469.

Li, A., Montaño, Z., Chen, V. J., & Gold, J. I. (2011). Virtual reality and pain management: current trends and future directions. Pain, 1(2), 147-157. doi: 10.2217/pmt.10.15.

Mahrer, N. E., & Gold, J. I. (2009). The use of virtual reality for pain control: A review. Current Pain and Headache Reports, 13(2), 100-109.

Malloy, K. M., & Milling, L. S. (2010). The effectiveness of virtual reality distraction for pain reduction: a systematic review. Clinical Psychology Review, 30(8), 1011-1018. doi: 10.1016/j.cpr.2010.07.001,

Marcora, S.M. (2016). Can Doping be a Good Thing? Using Psychoactive Drugs to Facilitate Physical Activity Behaviour. Sports Medicine, 46(1), 1-5.

Martin, J. B., Ahles, T. A., & Jeffery, R. (1991). The role of private body consciousness and anxiety in the report of somatic symptoms during magnetic resonance imaging. Journal of Behavior Therapy and Experimental Psychiatry, 22(1), 3-7. doi: 10.1016/0005-7916(91)90027-3.

Martin, M. A., & Metha, A. (1997). Recall of early childhood memories through musical mood induction. The Arts in Psychotherapy, 24(5), 447-454. doi: 10.1016/S0197-4556(97)00020-8.

Matsangidou, M., Ang, C. S., Mauger, A. R., Otkhmezuri, B., & Tabbaa, L. (2017, September). How Real Is Unreal? Virtual Reality and the Impact of Visual Imagery on the Experience of Exercise-Induced Pain. In IFIP Conference on Human-Computer Interaction (pp. 273-288). Springer, Cham.

Matsangidou, M., Ang, C. S., & Sakel, M. (2017). Clinical Utility of Virtual Reality in Pain Management: A Comprehensive Research Review from 2009 to 2016. British Journal of Neuroscience Nursing, 13(3), 70-80. doi: 10.12968/bjnn.2017.13.3.133.

Mauger, A. R. (2014). Factors affecting the regulation of pacing: current perspectives. Open Access Journal of Sports Medicine, 5, 209-214. doi: 10.2147/OAJSM.S38599.

McCaul, K. D., & Malott, J. M. (1984). Distraction and coping with pain. Psychological Bulletin, 95(3), 516-533. doi: 10.1037/0033-2909.95.3.516.

McGrath, P. J., Walco, G. A., Turk, D. C., Dworkin, R. H., Brown, M. T., Davidson, K., & Hertz, S. H. (2008). Core outcome domains and measures for pediatric acute and chronic/recurrent pain clinical trials: PedIMMPACT recommendations. The Journal of Pain, 9(9), 771-783. doi: 10.1016/j.jpain.2008.04.007.

Mehling, W. E., Gopisetty, V., Daubenmier, J., Price, C. J., Hecht, F. M., & Stewart, A. (2009). Body awareness: construct and self-report measures. PloS one, 4(5), e5614. doi: 10.1371/journal.pone.0005614.

Merskey, H., & Bogduk, N. (1994). Classification of chronic pain. Description of chronic pain syndromes and definitions of pain terms. IASP Press, Seattle, WA.

Miller, L. C., Murphy, R., & Buss, A. H. (1981). Consciousness of body: Private and public. Journal of Personality and Social Psychology, 41(2), 397-406. doi: 10.1037/0022-3514.41.2.397.

Morris, L. D., Louw, Q. A., & Grimmer-Somers, K. (2009). The effectiveness of virtual reality on reducing pain and anxiety in burn injury patients: a systematic review. The Clinical Journal of Pain, 25(9), 815-826. doi: 10.1097/AJP.0b013e3181aaa909.

Ohrbach, R., Crow, H., & Kamer, A. (1998). Examiner expectancy effects in the measurement of pressure pain thresholds. Pain, 74(2-3), 163-170. doi: 10.1016/S0304-3959(97)00174-7.

Pincus, T., Burton, A. K., Vogel, S., & Field, A. P. (2002). A systematic review of psychological factors as predictors of chronicity/disability in prospective cohorts of low back pain. Spine, 27(5), E109-E120.

Rutter, C. E., Dahlquist, L. M., & Weiss, K. E. (2009). Sustained efficacy of virtual reality Distraction. The Journal of Pain: Official Journal of the American Pain Society, 10(4), 391–397. doi: 10.1016/j.jpain.2008.09.016.

Schneider, S. (2007). A series of studies exploring the use of virtual reality for chemotherapy treatments. Oncology Nursing Forum, 34(1), 182-183.

Schneider, S. M., & Workman, M. L. (2000). Virtual reality as a distraction intervention for older children receiving chemotherapy. Pediatric Nursing, 26(6), 593-597.

Schneider, S. M., Ellis, M., Coombs, W. T., Shonkwiler, E. L., & Folsom, L. C. (2003). Virtual reality intervention for older women with breast cancer. CyberPsychology & Behavior, 6(3), 301-307. doi: 10.1089/109493103322011605.

Schneider, S. M., Kisby, C. K., & Flint, E. P. (2011). Effect of virtual reality on time perception in patients receiving chemotherapy. Supportive Care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer, 19(4), 555–564.

Schneider, S. M., Prince-Paul, M., Allen, M. J., Silverman, P., & Talaba, D. (2004). Virtual reality as a distraction intervention for women receiving chemotherapy. Oncology nursing forum, 31(1), 81–88.

Sil, S., Dahlquist, L. M., Thompson, C., Hahn, A., Herbert, L., Wohlheiter, K., & Horn, S. (2014). The effects of coping style on virtual reality enhanced videogame distraction in children undergoing cold pressor pain. Journal of Behavioral Medicine, 37(1), 156–165.

Tieri, G., Tidoni, E., Pavone, E. F., & Aglioti, S. M. (2015). Body visual discontinuity affects feeling of ownership and skin conductance responses. Scientific Reports, 5, 17139.

Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., & Fink, G. R. (2006). Neural signatures of body ownership: a sensory network for bodily self-consciousness. Cerebral Cortex, 17(10), 2235-2244. doi: 10.1093/cercor/bhl131.

von Baeyer, C. L., & Spagrud, L. J. (2007). Systematic review of observational (behavioral) measures of pain for children and adolescents aged 3 to 18 years. Pain, 127(1), 140-150. doi: 10.1016/j.pain.2006.08.014.

Wickens, C. D. (2008). Multiple resources and mental workload. Human Factors, 50(3), 449-455.

Wiederhold, M. D., & Wiederhold, B. K. (2007). Virtual reality and interactive simulation for pain distraction. Pain Medicine, 8(3), 182-188. doi: 10.1111/j.1526-4637.2007.00381.x.

Zatzick, D. F., & Dimsdale, J. E. (1990). Cultural variations in response to painful stimuli. Psychosomatic Medicine, 52(5), 544-557.